

STATUS AND OUTLOOK OF THE EDELWEISS WIMP SEARCH

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EDELWEISS is a direct dark matter search using cryogenic germanium heat-ionisation detectors, located in the Modane underground laboratory beneath the Alps. We summarize the final results of EDELWEISS I, which deployed up to almost one kg of detectors in its final stage. EDELWEISS II recently started commissioning runs. With an increased detection mass and better shielding, this stage aims to gain two orders of magnitude in sensitivity and to serve as a testbed for a larger, ton-scale experiment.

1 Introduction

Understanding the nature of dark matter in the universe is a major challenge for modern cosmology and astrophysics. One of the well-motivated candidates is the particle generically named WIMP (Weakly Interacting Massive Particle), such as the lightest supersymmetric particle. The main constraints when attempting to detect WIMPs are low event rate (less than a few events per kg of detector and per year) and small recoil energies (a few keV).

EDELWEISS (Expérience pour Détecter les WIMPs en Site Souterrain) is a direct dark matter detection experiment using the elastic scattering of WIMPs off target nuclei. EDELWEISS is situated in the Modane Underground Laboratory, in the Fréjus highway tunnel between France and Italy. An overburden of 1700 m of rock, equivalent to 4800 m of water, reduces the muon flux down to $4.5 \mu\text{m}^2/\text{day}$, that is about 10^6 times less than at the surface.

2 EDELWEISS I final results

EDELWEISS uses cryogenic germanium detectors, in a dilution fridge working at about 17 mK. Each detector has a NTD-Ge thermistor that measures the heat signal and two Al electrodes for the ionisation.¹ This technique of measuring two signals simultaneously allows an event by event discrimination between electronic (induced by photons or electrons) and nuclear (induced by neutrons or WIMPs) recoils (Fig. 1).²

EDELWEISS I used 320 g Ge detectors during several campaigns. Between 2002 and 2003, three 320 g detectors have been operated simultaneously in a cryostat shielded by 10 cm of Cu, 15 cm of Pb, 7 cm of internal roman Pb and 30 cm of paraffin. After a total fiducial exposure of 62 kg·day with an effective threshold of 15 keV, 59 events have been observed in the nuclear-recoil band.³ As shown in Fig. 3, most of the events are at low energy, between 10 and 30 keV. The simulated spectra of WIMPs having a scattering cross section on nucleons of 10^{-5} pb and

masses of 20, 40, 100 and 500 GeV/c² show that the events in the nuclear recoil band can not be explained by a single WIMP mass, a part of the spectrum has to be attributed to a non-WIMP background.

The two main sources of background that can mimic WIMP events are the mis-collected ionisation events and the neutrons. A two detector coincident event with both hits in the nuclear recoil band has been observed. The most likely source of this event is a neutron scattering. Monte-Carlo simulations predicted about two neutron single events for a total exposure of 62 kg-day. Nevertheless, the exclusion limit in Fig. 2 is derived without any background subtraction. It confirms, after a longer fiducial exposure, the previously published EDELWEISS I limits⁴.

EDELWEISS I, once the most sensitive direct dark matter search, became limited mainly because of the radioactive background (neutrons and surface events) and detection mass (the cryostat could not host more than three 320 g detectors). Therefore, the experiment has been stopped in March 2004, and is now replaced by EDELWEISS II.

3 EDELWEISS II

The second stage of the experiment is EDELWEISS II. By diminishing the radioactive background and increasing the detection mass, it should gain a factor of 100 in sensitivity compared to EDELWEISS I. Among the numerous improvements in EDELWEISS II, the main ones are: a new, larger, low consumption cryostat, a larger detection mass, improved detectors, new shieldings and an active muon veto, a class 100 clean room, new electronics and acquisition system.

In order to host up to 120 detectors, the new cryostat is larger (50 l) and has an innovative reversed geometry. Three pulse tubes replace liquid nitrogen cooling and a cold vapor reliquefier reduces helium consumption. The compact and hexagonal arrangement of the detectors should increase the neutron coincidence rate.

3.1 Radioactive background

The main limiting factor for EDELWEISS I was the radioactive background.

In a Ge detector, the ionisation signal coming from particles that interact very close to the surface can be mis-collected, hence the resulting events appearing in the nuclear recoil band. One way of dealing with this problem is by depositing a 60 nm Ge or Si amorphous layer on the crystal surface which diminishes the number of surface events⁸. All detectors used for EDELWEISS I 2002–2003 runs had such layers. Concentric electrodes provide a radial sensitivity allowing to select events occurring in the central part of the detector⁹ where the electric field is more homogeneous and the detector better shielded from its environnement.

A promising R&D project on surface events uses the sensitivity of NbSi thin film thermometers to athermal phonons¹⁰. As surface events have a higher athermal component, they can be identified and excluded during analysis. A 200 g detector with NbSi thin films on each end has already been tested in the EDELWEISS I cryostat with good results¹⁰ and is part of the EDELWEISS II setup for the first commissioning runs.

High energy neutrons are hard to moderate and can penetrate the shielding. When interacting with the detector, neutrons can mimic WIMP events, therefore they are an important issue for EDELWEISS II. Some of the ways of dealing with this problem in EDELWEISS II are a better shielding, a muon veto and the increase in the number of neutron coincident events.

3.2 *SciCryo*

Another R&D project, *SciCryo*^a, studies the possibility of using heat–scintillation bolometers for dark matter detection. For now, *SciCryo* has focused on light targets, complementary to Ge detectors and interesting for both neutron detection and spin–dependent interactions. So far, the most promising light target is Al₂O₃. Several nominally pure sapphire crystals have been tested in Lyon at room temperature and all of them have been seen to scintillate. Some of the crystals have also shown very encouraging low temperature light yields in tests performed at the IAS and the MPP. As a result of these tests, a 50 g IAS sapphire heat–scintillation detector has been included in the first EDELWEISS II commissioning runs to check its compatibility with the setup.

3.3 *EDELWEISS II near future*

Since January 2006, commissioning runs are taking place in order to check the level of microphonics and to test the new electronics and acquisition system. For now, eight detectors have been mounted in the cryostat: 4 Ge/NTD EDELWEISS I detectors, 2 new 320 g Ge/NTD detectors and 2 R&D detectors (a 200 g Ge/NbSi and a 50 g sapphire heat–scintillation detector). The goals for this year are to increase the number of bolometers to 28 and to define the next stage that may include up to 120 detectors.

4 Conclusion

EDELWEISS I, once the most sensitive direct dark matter search has been stopped in 2004. An important result of EDELWEISS I was the identification of the two main sources of background, surface events and neutrons. EDELWEISS II should gain a factor of 100 in sensitivity thanks to improved detectors, shielding, cleanliness and a higher detection mass. The main R&D projects concern the NTD and NbSi Ge detectors as well as the cryogenic heat–scintillation detectors. Preliminary results are expected in 2006.

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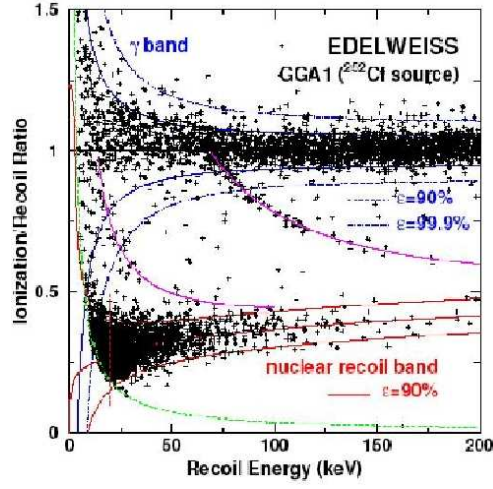


Figure 1: Ratio between the ionisation and the recoil energy versus the recoil energy. The separation between the electronic and the nuclear recoil band is excellent down to an energy of about 15 keV.

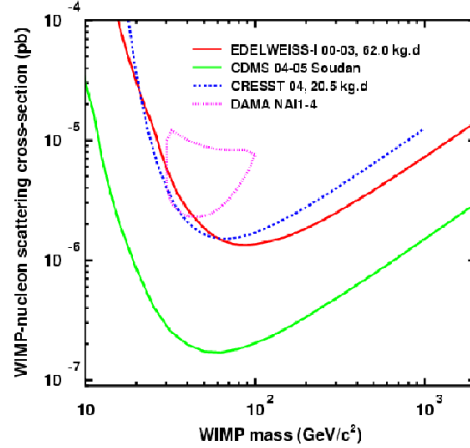


Figure 2: Spin independent exclusion limits on WIMPs, obtained with standard astrophysical assumptions within a 90% C.L.. Solid dark curve is the EDELWEISS I final limit, dashed curve is the CRESST limit from CaWO_4 ⁵, solid light curve is the CDMS limit from the Soudan mine⁶ and closed contour is the allowed region at 3σ C.L. from DAMA NaI1-4 annual modulation data⁷.

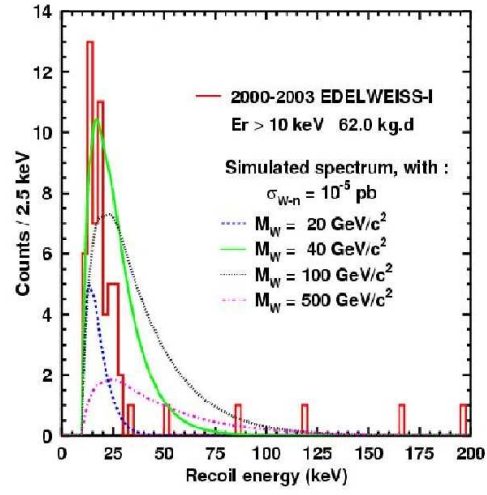


Figure 3: Energy spectrum of the EDELWEISS I experimental data compared to simulated spectra for different WIMP masses in the range of interest.